

# OPTIMISATION AND APPLICATION OF A LOW COST, COLORIMETRIC SCREENING METHOD FOR MERCURY IN MARINE SEDIMENT

CAVOURA, Olga<sup>a,c</sup>, DAVIDSON, Christine M.<sup>b</sup>, KATSIRIS, Nicholas<sup>a</sup>, KEENAN, Helen E.<sup>c</sup>

<sup>a</sup>*Department of Sanitary Engineering and Environmental Health, National School of Public Health, Athens, Greece*

<sup>b</sup>*WestCHEM, Department of Pure and Applied Chemistry, University of Strathclyde, Glasgow, UK*

<sup>c</sup>*Department of Civil and Environmental Engineering University of Strathclyde, Glasgow, UK*

\*corresponding author email: [okavoura@esdy.edu.gr](mailto:okavoura@esdy.edu.gr)

## Keywords

mercury; screening; colorimetric; marine; sediment; Elefsina

## Abstract

A rapid, inexpensive, colorimetric screening method for mercury (Hg) has been optimised to provide a semi-quantitative measurement of Hg concentration in marine sediment within the range 0.038 to 1.5 mg kg<sup>-1</sup> encompassing the interim sediment quality guideline (ISQG) value of 0.13 mg kg<sup>-1</sup> (CCME 1999) and the probable effects level (PEL) of 0.7 mg kg<sup>-1</sup> for Hg in marine sediment (CCME 1999). Neither salinity (up to 41 practical salinity units (psu)) nor sediment organic matter (OM) content (up to 10%) affected the performance of the method. Accurate results were obtained for spike recovery experiments and analysis of certified reference material (CRM) BCR 580 Estuarine Sediment. The method was applied to sediment samples from Elefsina Bay, Greece. Screening results indicated Hg contamination in the bay, with concentrations exceeding the PEL value. Findings were confirmed by quantitative analysis of the samples by cold vapour atomic absorption spectrometry (CV-AAS), where results in the range 1.4–2.96 mg kg<sup>-1</sup> were determined.

## Introduction

Sediment is the main environmental sink for Hg, containing an estimated >90% of the total Hg in the environment (Faust and Osman 1981). Aquatic organisms can be exposed to Hg through direct contact with sediment and Hg species can be biomagnified through the marine food chain, resulting in high levels in higher trophic level organisms. The main source of human exposure to Hg is through the consumption of contaminated fish, where regular consumption could exceed acceptable levels of intake currently set at  $0.1 \mu\text{g kg body weight}^{-1} \text{ day}^{-1}$  (EPA 2001). Assessment of sediment Hg levels is therefore necessary in order to determine potential for exposure of aquatic organisms, and ultimately human exposure to this potentially toxic element. Rapid, inexpensive screening is necessary to allow such assessments to be made in areas where resources are limited but the risk of exposure through the consumption of contaminated fish can be high (WHO 2013).

Over the last decade there has been much interest in developing portable sensors for rapid identification of Hg. These sensors work by registering an output such as light emission (Huange et al. 2016; Singh et al. 2014), or electrochemical response (Duarte et al. 2015; Zhou et al. 2013), or are based on colorimetry (Choi et al. 2014; Duan and Zhan 2015; Yallouz et al. 2008). The challenging step in the use of such sensors is application to 'real' samples. In the environment, their use is primarily limited to aqueous media (Bazzicalupi et al. 2013; Choi et al. 2014; Deng et al. 2013; Ding et al., 2016; Huber and Leopold 2016; Sedghi et al. 2017). Even then, in complex aqueous matrices such as groundwater and marine waters, difficulties are encountered: colorimetric sensors containing functionalized metal nanoparticles for example can become unstable when dissolved solids content is high (Duan and Zhan 2015) whilst filtration and dilution of samples is often necessary prior to analysis when using chemoluminescent sensors (Li et al. 2016; Huang et al. 2016; Jayabel et al. 2015). The analysis of solid samples adds extra difficulty, since an additional step is necessary to release Hg species for determination. To screen marine sediment for Hg, a method must incorporate both an initial digestion step, and a subsequent analysis step that is unaffected by the salt content of the marine environment and the chemicals used for sample digestion.

A Hg screening method that has been applied to freshwater sediment is the colorimetric paper-based sensor using copper(I)iodide (Yallouz et al. 2008). The reaction involved, which is specific for Hg (Gettler and Kaye 1950), produces cuprous mercury iodide,  $\text{Cu}_2[\text{HgI}_4]$ , a Hg complex with a characteristic orange colour. Not only can Hg be identified, but also, since the intensity of the colour produced on reaction with

copper(I)iodide is proportional to the Hg concentration, by comparing the colour obtained from a sample with colours obtained using standards of known concentration, a semi-quantitative determination of Hg content can be made, expressed as a concentration range. The method requires only basic laboratory glassware and a power supply and is therefore low cost and easy to implement. Its suitability has been demonstrated for the screening of fish (Yallouz et al. 2000; Ferreira et al. 2017), gold mining residues and fluvial sediments (Yallouz et al. 2008; Ferreira et al. 2017).

The aims of the current study were to more fully characterize the cuprous iodide based colorimetric Hg screening method, to assess its applicability to marine sediment, and to implement the method for screening of Hg levels in marine sediment from Elefsina Bay, Greece.

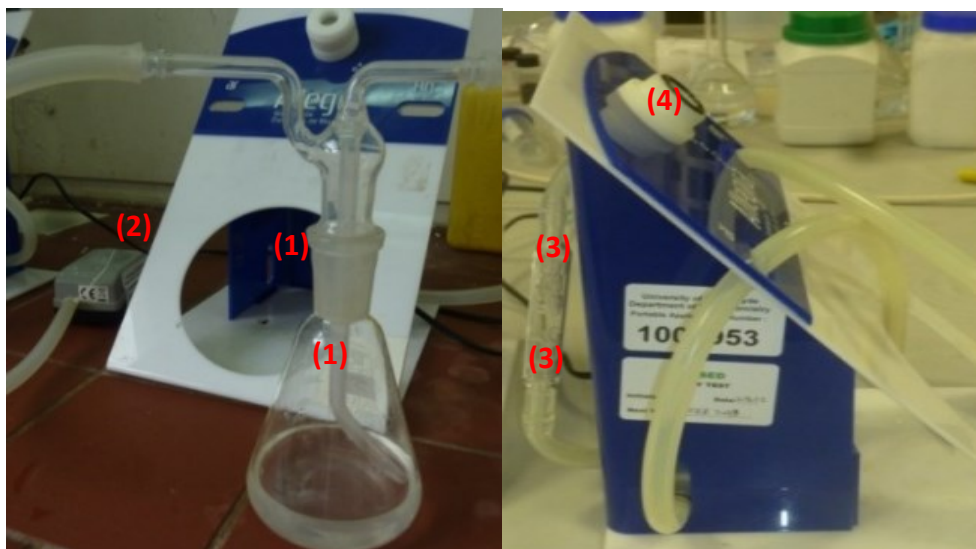
## Materials and methods

### General procedures

Chemicals were of analytical grade or higher purity. Glassware was soaked in 10% (v/v)  $\text{HNO}_3$  (> 65%, for trace analysis, Sigma-Aldrich Company Ltd. Dorset, UK) overnight and rinsed with deionised (DI) water before use. Glass containers were used for storing Hg samples, standard solutions and reagents. A 10 mg  $\text{L}^{-1}$  Hg stock solution in 10% (v/v)  $\text{HNO}_3$  was prepared from a 1000 mg  $\text{L}^{-1}$  commercial Hg standard solution ( $\text{Hg}(\text{NO}_3)_2$ , Certipur, Merck, Leicester, UK). Reagent-matched standard solutions with Hg concentration < 10 mg  $\text{L}^{-1}$  were prepared daily by appropriate dilution of the stock solution in DI water.

### Screening procedure

The apparatus (Fig. 1), reagents and procedures used for the screening method were based on the method described by Yallouz *et al.* (2008). Briefly, 10 g test portions of solid samples were weighed accurately into a conical flask, fitted with a water-filled cold finger, and digested in 25 mL *aqua regia* at 80 °C for 30 min. using a water bath. After cooling to room temperature, 50 mL DI water was added and  $\text{Hg}^{\text{II}}$  species were reduced to  $\text{Hg}^0$  with 5 mL  $\text{SnCl}_2$  (50% w/v in HCl) without filtration of the digest. By using an aquarium pump and aeration duct to bubble air through the sample,  $\text{Hg}^0$  was transferred *via* a condenser to a preconditioned detecting paper coated with copper(I)iodide and held in a specially constructed holder (Cetem, Centro de Tecnologia Mineral, Brazil), where  $\text{Cu}_2[\text{HgI}_4]$  was formed on reaction with the coating.



**Fig. 1** Apparatus for Hg reduction and determination as described by Yallouz et al. (2008). An aeration duct is positioned inside the conical flask (1). One arm of the duct is connected through tubing to an aquarium pump (2) and the other arm is connected to the condenser (3), which is attached to the detecting paper holder (4)

Since the intensity of the colour was proportional to the amount of Hg in the sample, a semi-quantitative determination of Hg concentration was obtained by comparison of the colour intensity produced from Hg in standard solutions, analyzed in the same manner (but omitting the digestion step) (Fig. 2). Sample Hg concentrations were reported as a range corresponding to the lower and higher standard solution concentrations producing less and more intense colors respectively than the sample. For example, if the color intensity obtained from sample analysis lay 'in between' the intensities of colors obtained for two standard Hg concentrations of 10 and 30  $\mu\text{g L}^{-1}$  respectively, a semi-quantitative sample concentration of 10–30  $\mu\text{g L}^{-1}$  was reported.



**Fig. 2** Increasing colour intensity of Hg complex formed on copper(I)iodide-coated detecting papers following analysis of standards with increasing Hg concentration (from left to right: blank, 15, 35, and 55  $\mu\text{g L}^{-1}$ )

## Method characterization

### *Flow rate and repeatability*

The effect of aeration pump flow rate on the reproducibility of the colour obtained from reaction of  $\text{Hg}^0$  vapor with the detecting papers was tested using two, fixed-flow rate aquarium pumps: an Elite Pro that operated at a flow rate of 2.5  $\text{L min}^{-1}$  (provided with the detecting papers and holder by Cetem, Centro de Tecnologia Mineral, Brazil) and an AquaAir Mini (Interpet, Surrey, UK) that operated at a flow rate of 1  $\text{L min}^{-1}$ . Three replicate analyses of a 40  $\mu\text{g L}^{-1}$  Hg standard were performed using each pump and flow rate.

### *Method range and concentration discrimination*

The range of the method was assessed using standard solutions (75 mL) containing from 5 to 300  $\mu\text{g L}^{-1}$  of Hg. For a 10 g sediment sample this corresponds to a sediment Hg concentration range of 0.038 to 2.25  $\text{mg kg}^{-1}$ . This range covers background (unpolluted) mercury sediment concentrations, considered to be 0.01–0.2  $\text{mg kg}^{-1}$  (Boszke et al. 2003), samples with Hg content around the ISQG value of 0.13  $\text{mg kg}^{-1}$  and contaminated sediment samples with Hg content above the PEL of 0.7  $\text{mg kg}^{-1}$  (CCME 1999). Colour discrimination was tested by analyzing standard solutions differing in concentration by various amounts e.g. 10  $\mu\text{g L}^{-1}$ , 20  $\mu\text{g L}^{-1}$ , 50  $\mu\text{g L}^{-1}$ , within the above range.

### *Effect of sediment organic matter content*

Sediment OM contributes significantly to adsorption of Hg (Skylberg et al. 2006), hence can alter the efficiency of Hg extraction from sediment samples, leading to incorrect results being obtained. To investigate whether this affected the screening method, results for the determination of Hg in synthetic sediment containing no OM (sand pit sand, B&Q, Glasgow, UK) and in synthetic sediment containing 10% OM (75% sand + 10% silt + 5% clay + 10% humus) were compared. This selection covered typical sediment OM content. Duplicate 10 g test portions of each synthetic sediment were spiked with 3  $\mu\text{g}$  Hg by

addition of 300  $\mu\text{L}$  of the 10  $\text{mg L}^{-1}$  Hg stock solution (to give a resultant Hg concentration of 0.3  $\text{mg kg}^{-1}$ ) then mixed well, covered and left overnight before digestion and analysis. Synthetic sediment and sand blanks (without addition of Hg) were also analysed.

## Applicability of method to the marine environment

### *Effect of salinity and seawater on method performance*

The effect of increasing salinity on the screening method was first tested by using potassium chloride (KCl, GPR, BDH Laboratory Supplies, Poole, UK) to prepare a series of Hg standard solutions (40  $\mu\text{g L}^{-1}$ ) with increasing salinities from 0.01 to 41 psu (the latter representing the salinity of seawater). The salinity was determined based on an *in situ* electrical conductivity measurement at 20 °C and P = 10 kPa, and converted to salinity using Flinders conductivity converter (<http://www.es.flinders.edu.au>).

Performance was also compared for analysis of series of DI and sea water standard solutions. Seawater obtained from the intertidal zone at Loutsas, Greece (37.969° N, 24.008 ° E) and DI water were spiked with appropriate volumes of 10  $\text{mg L}^{-1}$  Hg stock solution to produce pairs of test solutions with Hg concentrations in the range 5–200  $\mu\text{g L}^{-1}$ . The colours obtained for pairs of the same concentration were compared to assess potential interferences from sea water.

### Method performance for marine sediment

Method efficiency in marine sediment was tested by both spike recovery experiments and analysis of a CRM. The sediment was obtained from the intertidal zone at Lochgilphead, UK (56.02° N, 5.44° W), air dried, and passed through a 2 mm mesh stainless steel sieve before use. Portions (10 g) were spiked with 1.5 and 6  $\mu\text{g}$  Hg (by addition of 150 or 600  $\mu\text{L}$  of the 10  $\text{mg L}^{-1}$  Hg stock solution), mixed thoroughly, covered and left overnight, before being digested and screened for Hg. Blank sediment was also analyzed. The CRM was BCR 580 Estuarine Sediment (Institute for Reference Materials and Measurements, Geel, Belgium) containing  $132 \pm 3 \text{ mg kg}^{-1}$  Hg. Smaller test portions (approximately 0.02 and 0.04 g) of the CRM were analysed because of its high Hg content.

### Application



### Study site

Sediment was taken from the Elefsina Bay (also known as the Gulf of Elefsina), 20 km west of Athens, Greece. With the island of Salamina to the south, the bay is sheltered and water mixing is poor. Two narrow channels connect the bay to the Aegean Sea (Fig. 3).



**Fig. 3** Elefsina Bay, Greece, showing sampling locations

The bay has a surface area of 67 km<sup>2</sup>, a maximum depth of 33 m and receives effluent from some of the largest industrial plants in Greece, such as shipyards, oil refineries, paper and cement industries and metal extraction facilities. The main municipal effluent from Athens, which until 1995 was without treatment, is also discharged into the bay. In 2005, the bay was recognised as an area of major environmental concern (EEA 2005).

### Sampling

Nearshore locations were selected along the bay in the vicinity of specific industries and sample coordinates recorded (Garwin eTrex 10 GPS unit). Specifically, locations A1 and A11 were in the vicinity of ship yards; A2 and A4 were in the area of oil refineries; A8 was

near a ship disassembly unit; and A5 was the location receiving the outfall from the Agios Georgios stream that contains effluent from many industries. Samples were taken at approximately 500–1000 m from the shore from a naval motor launch using a grab sampler and placed in glass wide mouth bottles for transport to the laboratory.

### *Sediment preparation*

Sediment samples were dried in a natural convection drying oven (Binder E28, VWR International GmbH) at 30 °C and sieved (2 mm mesh, stainless steel) before storage in glass bottles. Each dried, sieved sample was coned and quartered to obtain a representative test portion for analysis.

### Quantitative determinations

To assess the performance of the screening test, quantitative determination of total Hg concentration was performed using CV-AAS (PE 2006). Briefly, after microwave assisted digestion of 0.5 g test portions with 10 mL HNO<sub>3</sub> (175 °C, 20 min) (Berghoff Speedwave MWS-2 microwave system), 10 mL DI water was added to each digest, following which digests were filtered and diluted to a final volume of 50 mL with further DI water. Analysis was performed following reduction with 3% NaBH<sub>4</sub> using a MHS-10 Hg/Hydride system (Perkin Elmer, Massachusetts, USA) operated in cold vapour mode. Moisture content was determined on dried, sieved test portions (BS 2000) and OM content was estimated by loss on ignition (Schumacher 2002).

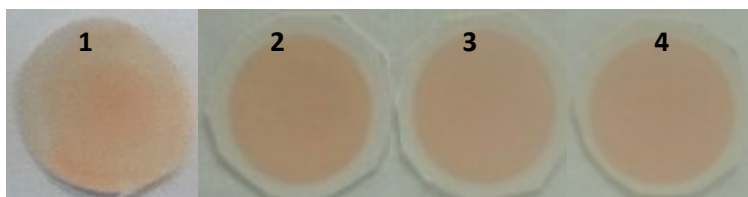
## **Results and discussion**

### Method characterization

#### *Flow rate and repeatability*

Results obtained for triplicate analysis of the 40 µg L<sup>-1</sup> standard solution using a flow rate of 2.5 L min<sup>-1</sup> proved unsatisfactory. Colour development was uneven and there was no distinct edge to the coloured complex formed (Fig. 4, paper 1). Delivering the Hg<sup>0</sup> vapor to the detecting paper more slowly (1 L min<sup>-1</sup>) yielded reproducible results, a generally uniform response across the sensitive area of the detecting paper, and a spot with distinct edges (Fig. 4, papers 2, 3, 4). The lower flow rate was therefore selected for future use.





**Fig. 4** Response obtained for analysis of a 40 µg L<sup>-1</sup> standard solution using the Elite Pro pump at a flow rate of 2.5 L min<sup>-1</sup> (paper 1) and the AquaAir Mini pump at a flow rate of 1 L min<sup>-1</sup> (papers 2, 3, 4)

#### *Method range and concentration discrimination*

Concentrations of 5 µg L<sup>-1</sup> Hg were distinguishable from the blank, making this the lower limit of screening in solution (equivalent to a limit of detection around 0.04 mg kg<sup>-1</sup> for analysis of a 10 g sediment sample). A difference in colour intensity visible to the eye could be seen between standards differing in Hg concentration by 20 µg L<sup>-1</sup>, up to a Hg concentration of 150 µg L<sup>-1</sup> (Fig. 5, top row). Above a Hg concentration of 150 µg L<sup>-1</sup> colour differences became harder to discern. There was no obvious increase in colour intensity between 200 and 300 µg L<sup>-1</sup>, indicating that 200 µg L<sup>-1</sup> (which is equivalent to 1.5 mg kg<sup>-1</sup> for analysis of a 10 g sediment sample) was the effective upper limit of sensitivity for the sensor.

#### *Effect of sediment organic matter content*

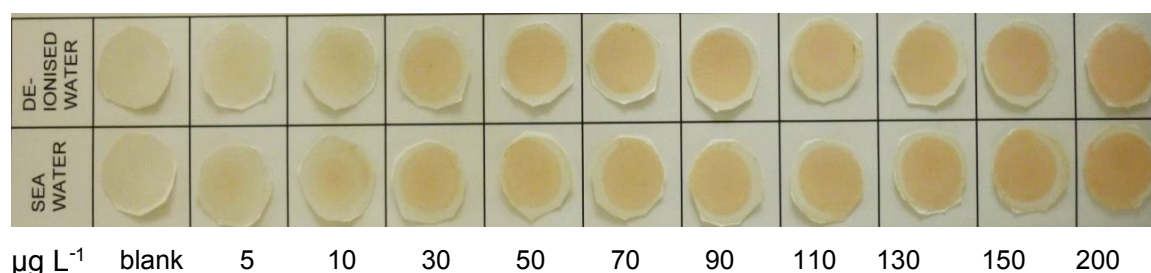
After spiking 10 g test portions of synthetic sediment without OM, and 10 g test portions of synthetic sediment containing 10% OM, with 3 µg Hg, the screening method was applied both to the sediment samples and to standards containing 1.1, 2.6 and 4.1 µg. The colours intensities obtained for the samples were indicative of a Hg content in the range 2.6–4.1 µg per sample, which corresponds well to the 3 µg added. At least for the specific samples and contact time studied, the presence of up to 10% OM did not appear to affect the method performance. No Hg was detected in either the reagent blank or the unspiked synthetic samples.

#### *Applicability of screening method to the marine environment*

#### *Effect of salinity and seawater on method performance*

A series of 40  $\mu\text{g L}^{-1}$  Hg standard solutions was prepared with differing salinities; 0.01, 10, 21, 30, 33 and 41 psu. Regardless of the salinity, all standards produced the same colour intensity on screening indicating that salinity does not affect intensity.

Two series of standard solutions with Hg concentrations ranging from 5 to 200  $\mu\text{g L}^{-1}$  were prepared, one series in DI water and the other in seawater. Similar intensities were obtained for standard solutions of the same concentration, regardless of the matrix (DI water or seawater) (Fig. 5) indicating that the seawater matrix did not interfere with the screening method.



**Fig. 5** Increase in colour intensity obtained from screening standard solutions containing 5, 10, 30, 50, 70, 90, 110, 130, 150 and 200  $\mu\text{g L}^{-1}$  of Hg prepared in deionised water and seawater

#### Method performance for marine sediment

Marine sediment (10 g portions) was spiked with 1.5  $\mu\text{g}$  and 6  $\mu\text{g}$  Hg. The colour intensities produced on screening were compared to intensities obtained for standard solutions containing 0.75, 3.75 and 7.5  $\mu\text{g}$  Hg. The samples spiked with 1.5  $\mu\text{g}$  Hg gave colour intensities indicative of a Hg content in the range 0.75–3.75  $\mu\text{g}$ , and samples spiked with 6  $\mu\text{g}$  Hg gave colour intensities indicative of a Hg content in the range 3.75–7.5  $\mu\text{g}$ , corresponding to the amount of Hg added.

Portions of CRM BCR 580 Estuarine Sediment containing 2.81 and 5.48  $\mu\text{g}$  Hg were screened and the colours obtained compared to intensities obtained for standard solutions containing 1.1, 2.6 and 4.1  $\mu\text{g}$  Hg. The samples containing 2.81  $\mu\text{g}$  Hg gave colour intensities indicative of a Hg content in the range 2.6–4.1  $\mu\text{g}$ , and the samples containing 5.48  $\mu\text{g}$  Hg gave colour intensities indicative of a Hg content > 4.1  $\mu\text{g}$  Hg, corresponding to the expected range (Table 1). The procedure was therefore considered suitable to screen sediment samples from Elefsina Bay.

**Table 1** Screening results for Hg in marine sediment spiked with 1.5  $\mu\text{g}$  and 6  $\mu\text{g}$  Hg and for certified reference material (CRM) BCR 580 containing  $132 \pm 3 \text{ mg kg}^{-1}$  Hg

Spiked sediment weight	Hg added ( $\mu\text{g}$ )	Hg found ( $\mu\text{g}$ ) <sup>a</sup>
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10 g (replicate 1)	0	< LOD
10 g (replicate 2)	0	< LOD
10 g (replicate 1)	1.5	0.75–3.75
10 g (replicate 2)	1.5	0.75–3.75
10 g (replicate 1)	6	3.75–7.50
10 g (replicate 2)	6	3.75–7.50
CRM weight (g)	Hg content (µg)	Hg found (µg) <sup>b</sup>
0.0210	2.81	2.6–4.1
0.0412	5.48	> 4.1

<sup>a</sup> Sediment results compared to those for standard solutions containing 0.75, 3.75 and 7.5 µg Hg

<sup>b</sup> CRM results compared to those for standard solutions containing 1.1, 2.6 and 4.1 µg Hg

## Application

Screening of sediment samples from Elefsina Bay identified Hg contamination at all locations. Initial screening was performed using 10 g test portions, as in method development, and comparison made with the colour obtained from standard solutions (75 mL) containing up to 70 µg L<sup>-1</sup> of Hg (equivalent to a maximum sediment Hg concentration of 0.5 mg kg<sup>-1</sup>). Since sediment concentrations appeared to be either very close to or above this value, screening was repeated using 1 g sediment samples and standard solutions (75 mL) of Hg concentration 10, 50 and 100 µg L<sup>-1</sup> (equivalent to sediment concentrations of 0.75, 3.75 and 7.5 mg kg<sup>-1</sup> Hg). Results for locations A2 and A5 gave Hg concentrations in the range 0.75–3.75 mg kg<sup>-1</sup>, while sediments from A1, A4, A8 and A11 had Hg concentrations between 0.38 mg kg<sup>-1</sup> (the procedural LOD for analysis of a 1 g samples) and 0.75 mg kg<sup>-1</sup> (the response for the lowest concentration standard solution) (Table 2).

**Table 2** Screening results for Hg content, Hg concentration as determined by cold vapour atomic spectrometry (CV-AAS) and sediment organic matter (OM) content in samples from Elefsina Bay

Locations (E to W) and potential pollution source in brackets	Coordinates (lat., long.)	Screening result (mg kg <sup>-1</sup> ) (1 g sample)	Total Hg by CV-AAS <sup>a</sup> (mg kg <sup>-1</sup> )	OM (%)
A1 (shipyard)	38.010° N, 23.590° E	0.38–0.75	1.93 (1.77, 2.08)	8.36 (8.06, 8.66)
A2 (oil refinery)	38.020° N, 23.595° E	0.75–3.75	1.88 (1.73, 2.03)	8.96 (7.51, 10.4)
A5 (Agios Georgios stream)	38.030° N, 23.590° E	0.75–3.75	2.96 (2.19, 3.73)	7.23 (6.76, 7.71)
A8 (dissassembly unit)	38.038° N, 23.554° E	0.38–0.75	1.40 (1.15, 1.66)	8.09 (7.36, 8.87)
A4 (oil refinery)	38.038° N, 23.507° E	0.38–0.75	1.50 (1.38, 1.61)	11.8 (11.0, 12.6)
A11 (shipyard)	38.029° N, 23.495° E	0.38–0.75	2.86 (2.20, 3.51)	9.08 (8.07, 10.1)

<sup>a</sup>CV-AAS and OM results given as mean of two values (individual results shown in brackets)

Mercury concentrations determined by CV-AAS ranged from 1.40 to 2.96 mg kg<sup>-1</sup>, with highest concentrations found in locations A5 (outfall of Agios Georgios stream) and A11

(shipyard). High Hg concentration at position A5 is probably a result of effluent discharge from industries known to release Hg such as cement manufacture and metal extraction while the use of phenylmercury acetate as an antifouling agent in ship paints, which was common until the 1990s, may explain the higher results at locations A11. Although there was variation between results for duplicate analyses, the concentration of Hg in all samples exceeded not only the ISQG value of  $0.13 \text{ mg kg}^{-1}$ , but also the PEL of  $0.7 \text{ mg kg}^{-1}$  for Hg in marine sediment (CCME 1999), the latter being the concentration above which adverse effects are frequently observed in aquatic organisms. The OM content of the samples ranged from 7.23 to 11.8%, with highest OM content at position A4. The proximity of this location to an oil refinery could explain the higher OM observed in this area.

Screening and quantitative Hg determination gave consistent results for samples A2 and A5. Although screening identified the presence of Hg for samples A1, A4, A8 and A11, the screening results were lower than the results obtained from quantification (Table 2). Lower results are not thought to be a consequence of OM content, since samples for which screening gave a result in the correct range did not differ markedly in OM content from those for which screening gave a lower assessment. A possible explanation for the lower screening results is that the digestion procedure used in the screening method was less vigorous: while digestion in the screening method was performed at a relatively low temperature of  $80^\circ\text{C}$  (using *aqua regia*), for quantitative determination microwave digestion was carried out at  $175^\circ\text{C}$  (using concentrated  $\text{HNO}_3$ ). Harsh digestion conditions are necessary if the determination of all forms of Hg, including less mobile forms, such as  $\text{HgS}$ , is desired. However, insoluble, stable forms of Hg are less likely to be released under environmental conditions and are not available for biomethylation. Milder extraction conditions, such as those used in the screening method, are more representative of environmental mobility and give a clearer indication of potential for exposure.

## Conclusions

A colorimetric screening method for semi-quantitative determination of Hg in the marine sediment was found to have a sensitivity range from  $0.038$  to  $1.5 \text{ mg kg}^{-1}$ . Method performance was unaffected by salinity up to 41 psu, the presence of a seawater matrix and sediment OM content up to 10%. Results in the expected ranges were obtained when the method was applied to spiked (uncontaminated) marine sediment samples, and CRM BCR 580 Estuarine Sediment. Results obtained for screening of sediments from the Elefsina Bay, Greece, sometimes underestimated the true Hg content as determined

by CV-AAS, probably due to milder digestion conditions used. However Hg contamination potentially exceeding the PEL level of  $0.7 \text{ mg kg}^{-1}$  (CCME 1999) was identified at all locations sampled and the determination of Hg concentration using milder digestion conditions is more indicative of environmentally mobility Hg concentrations and potential for exposure. Quantitative analysis confirmed sediment Hg concentrations in Elefsina Bay ranged from  $1.4$  to  $3.0 \text{ mg kg}^{-1}$ . Further work will explore the use of battery-powered aerating pumps and portable sample digestion/extraction apparatus with the goal of developing a methodology that can be fully implemented in the field to allow initial identification of contaminated marine sediment that can then be taken to a laboratory for quantitative analysis where necessary.

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